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TITLE OF THE INVENTION

Ultra high information storage and/or non-volatile memory apparatus, system and method hereof.

CROSS-REFERENCE TO RELATED APPLICATION

PCT application Ser. No. PCT/NL03/0387, entitled " Mass information storage and non-volatile memory device, and method, apparatus and system hereof." filed on May 26, 2003 herewith for Wilhelmus Versteegen and Nardy Cramm is incorporated herein by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

REFERENCE TO SEQUENCE LISTING, A TABLE, OR A COMPUTER PROGRAM LISTING COMPACT DISK APPENDIX

Not applicable.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of art to which this invention relates is ultra high density, ultra-high capacity, high data rate information storage and memory apparatus and methods. Specifically, this invention relates to a method for writing, reading, and erasing information to a material by manipulating the material's surface.

2. Description of the Related Art

For mass information storage, magnetic recording is the prime storage technology today. The magnetic hard disks and CD-ROMS have been increasing their capacity in line with Moore's law, almost doubling every year. However, after about 46 years of successful information storage the

magnetic storage technology appears to have reached the end of its elementary restrictions. Surface densities achieved by today's magnetic recording technologies will soon reach a limit. It has been predicted that the super paramagnetic limit, below which magnetic bits are not stable at room temperature, will limit the densities of magnetic recording media to about 15.5 Gb/cm2.

Although the current longitude magnetic information storage has considerable advantages, such as high storage capability, it also has with several drawbacks, such as comparatively low information density, high power consumption, the relatively slow writing and replication, limited reliability as a consequence of several fragile moving parts and the above-mentioned super paramagnetic limit.

Nowadays, there is a clear demand for replacement of the current magnetic recording storage by a high capacity and high-density storage device. For purposes of mass data storage, this storage device should have a density of at least 1 Tb/cm2 and a capacity of at least 1 Terabyte, preferably dressed within a small and light embodiment. High access and transfer rates for reading and writing is essential for fast replication and retrieval of the information stored. Fast, proper and reliable erasing is another essential requirement. Other preferred amenities include low-power consumption, low-cost manufacturing, high reliability, high data security, and shock resistance.

Physically smaller storage devices were imagined after the discovery of the Scanning Tunnelling Microscope. The STM made everyone aware that atomic scale motion could be achieved. A long period of investigation has yielded a number of active efforts to produce so-called "probe storage" devices, all using Micro-Electro-Mechanical-Systems (MEMS) for the positioning mechanisms, but different schemes for the actual writing and reading of the data bits. The MEMS part of the devices is used to position a small movable element with respect to the read-write components. The very dense packing of the data is accomplished by an x-y mover (Cartesian coordinate system) rather than the rotating disk and radial arm motion of the disk drive (Cylindrical coordinate system).

For the read-write mechanism, Hewlett Packard is perfecting a phase-change scheme in its Atomic Resolution Storage program; Carnegie-Mellon University is pursuing a magnetic scheme in its CHIPS program. IBM is working on a physical deformation of a polymer in its Millipede (now NanoDrive) program. Other approaches are also being tried using charge trapping (Canon), ferroelectric polarization (HP), and probe phase change (LETI) to name a few. These and other "probe storage" approaches are in various stages of development and a race is on to bring them into the hands of customers.

Patent 5,835,477 shows various concepts for information storage systems and operations. Project Millipede employs an array of thousands of sharp silicon composite rods, all holding a sharp tip of about 10 nm, each tip and cantilever are addressed individually multiplex drivers. In the millipede concept, the nano-tips punch indentations into a thin polymer film coating a silicon substrate, which moves in x and y directions. The x and y scanning distances correspond to the pitch between two tips. Electronics controls the quasi-parallel operation of the array; one line is operated in parallel, while the others are addressed in a time-multiplexed sequence. The indentations represent individual bits, similar to the old punch card systems that were common towards the end of the 19^{th} century.

Each rod is comprised of two materials that conduct heat at different rate. The process works by heating a resistor inside the rod, heating it to about 400 degrees. The tip remains only a few microseconds on the film. As the materials within the rod conduct heat at different rates, the rod bends towards the polymer film; this inserts its now-hot tip into the polymer, melting a punch. To read the data, the resistor is operated at a lower temperature of about 300 degrees, which does not melt the material. This allows the tip to interpret the pattern embedded in the film, without changing the pattern of the indentations. When the tip drops into an indentation, the resistor is cooled by the resulting better heat transportation, which is detected as read-back signal. Time-multiplex electronic drivers, connected through peripheral bonding pads address each tip individually for parallel operation.

The tips of this Micro Electro Mechanical System (MEMS) give the ultimate density, whereas data rates are the result of the massive parallel operation of those tips. According to more current released information of the IBM Almaden Research Center, recent experiments showed that individual tips could support data rates as high as 1-2 megabits per second, while another 1,024-tip experiment achieved an areal density of 200 Gb/s, whereas a next-generation Millipede prototype is expected to hold four times more tips; 4,096 in a 7 mm-square (64 by 64) array. Reusing the polymer occurs by a second indentation next to the first, causing the hole to fill in by the edges of the second. To overwrite data, the tips are supposed to make series of offset pits that overlap so closely, their edges should fill in the old pits, erasing the individual data, making it re-writable. While current data rates of individual tips are limited to some kilobits per second, range, which amounts for a few megabits for an entire array, according to more recent information issued, faster electronics should allow for faster higher rates.

Another, yet unknown issue with data rates (transfer and access), as a direct result of increasing capacity is the, so far unidentified effect, which manifests itself when information storage becomes exceeding the Multi-Terabyte capacity. This phenomenon, inhere called the "Principle of Uncertainty", shows a non-linear expansion of uncertainty as capacity of information storage increases. The amount of uncertainty will have a coupling, decelerating reflection on the speed of the internal communications, and also a coupling reducing effect on access time of the information, and a coupling slow up reflection on transfer times.

Since the object is to create an ultra-high capacity, ultra-high density, high data rate information storage device and methods, including the aforementioned amenities, the effects of uncertainty need to be directed. Since the effects of uncertainty become readily noticeable above the Multi-Terabyte information storage capacity, and exerts its decelerating influence on anything, especially in data rates, the "Principle of Uncertainty" will be explained and described and a method to deal with these effects will be disclosed and incorporated herein.

Directly related to reading and writing, as well as data rates is addressing and/or positioning. So far this has proved to be a decelerating, expensive and complicated feature. The current magnetic recording mass data storage utilizes rotating disk and radial arm motion of the disk drive, called a cylindrical coordinate system. The relatively slow replication of information storage will cause insuperable difficulties when data storage will surpass the Terabyte-boundaries

In addition, small scale processing capability producing ultra-high density storage has to contend with expensive equipment as well as limited capacity. Even if one could increase the storage density in combination with high capacity, one still has to overcome other major obstacles, which is addressing, as well as the time required to access (a certain part of) the information and/or data. The storage device's and method's usefulness are limited if it takes too much time to store or retrieve the information. In addition, addressing is a complication. Without addressing, information cannot be read. In other words, in addition to high storage density, one must also find a way to increase fast access time and fast transfer rates.

Furthermore, as far as data rates and separation of storage and memory concerns, the time required to access information in the current magnetic recording is mostly depending on access time and transfer rates. Commonly standard storage devices use a semi permanent scheme for storing information. This information is generally maintained even if the power is lost to the storage device. We call this kind of storage non-volatile. Storage devices typically have large capacity. The design of storage devices is a compromise between maintaining a low price and access time (the time required to access the first bit of desired information). This compromise is achieved by using a minimum number of the complex, expensive components (such as recording heads, drive motors, etc.) but a large amount of the inexpensive components (which is primarily the recording medium). Rigid disks, flexible disks, magnetic tapes, CD-ROM's, CD-RW's, DVD-ROM's and DVD+RW's are examples of these kinds of devices. Components that store data for a short time within a computer are called memory devices. At the same time as the computer is powered up, all the information is kept in memory by the live

circuitry. When there is an interruption of power, the majority of the information within computer memory is lost. Therefore, this memory is called volatile. Some of the memory (DRAM) has to be refreshed even when the power is on. When using computing machines in our own personal experience, we never think that some of the volatile memory is being rewritten continuously, because the computer is doing that for us in the background. The speed of typical memory is gained by having a random access architecture, which provides an address to every bit whether or not it is needed by the processor at any given moment. The random access designs are achieved by using semiconductor technology based on photolithography. Hence, typical computer memory is very similar in cost to other semiconductor devices, like microprocessors. RAM memory is the most expensive form of information storage, but it can be as fast as the fastest processors (nanosecond delay times to get to the first desired bit).

The fundamental architectural choices behind memory and storage, stems from their data access architecture. Storage is based on a movable read-write mechanism, which can be positioned to access any desired bit of information. A way to speed up the mechanical system of storage is to use smaller components (or employ steerable beams to access the data).

Non-volatile memory is also being pursued actively by a large number of parties, and a few examples of these technologies are already on the market. Flash memory exists today, as a non-volatile memory technology. Flash has the disadvantage that it is not infinitely recyclable and not fast enough in writing to work alongside processors. Researchers are looking at non-volatile memory technologies different from the flash charge storage scheme. Leading the way are MRAM (Magnetic RAM), FeRAM (Ferroelectric RAM; modest capacity products are available today from Ramtron, and many others working on it), phase change (Ovonyx has announced partnerships with Intel and STM), NROM (charge trapping in nitrides, pursued most actively by Saifun Semiconductors and AMD) and polymer memory (pursued by a number of companies). Each of these non-volatile memory technologies has its advantages and disadvantages.

Another essential feature for a data storage device to replace the present magnetic recording is erasing. Aside from the existing method, so far, all other erasing methods for stored information on special materials, which are in principle suitable as erasable storage media, are either too slow or cannot be fine-tuned to facilitate erasure of single bits on a nanoscale.

Last but not least, in view of the disadvantages of existing storage media, in principle suitable to be used for reading, writing and erasing on a nanoscale, there is still a need for improved materials and storage concepts, in particular to overcome problems inherent to the erasing process, in addition to density matters with regard to nanomaterials.

As indicated, for decades researchers have been working to increase storage density, capacity, memory and time required accessing the data, as well as trying to reduce cost of data storage devices such as magnetic hard-drives, chips, optical drives, and random access memory. However, increasing the storage density is becoming rather difficult; conventional technologies appear to be approaching fundamental limits on storage density. So far, alternatives do not offer viable solutions for mass data storage, because many parts of the hardware equipment used to perform reading, writing, deleting and erasing are either very sophisticated and expensive, or do not facilitate the least requirements to replace the magnetic recording storage (yet).

Several issues, among competing low-cost manufacturing of the cantilevers and tips, reading and writing reliability as a result of dependability on the strength of the tips, reliable erasing techniques, mechanical wear of storage media, and improvements on the data rates still need to be worked out.

For the above mentioned reasons, there is a need in the art for high-density, high-capacity method of reading and writing, deleting and erasing, which does not suffer from the drawbacks associated with the current technologies for information storage and memory.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A shows a side view of a "General Unified Storage" (or "GUS") storage device in accordance with the present invention.

Above the top of the storage medium (12) resides the wafer (14) in which the MWNT's are attached. The storage medium is attached on a frame (13). This frame is connected via cogwheels (16.1 and 16.2) driven by motors (11.1 and 11.2) that move it in X direction. Other motors move it in the Y direction. All motors are positioned underneath the storage medium. The laser diode (15), used for erasing process, is mounted underneath the medium.

Figure 2A to 2B shows an example of how a Smartey Tube, as described above, can look like. In this figure, a MWNT (20) consist of (at least one) outer nanotube (22) with some chirality and length and (at least one) inner carbon nanotube (21). In figure 2B the outer nanotube has been opened to give a better view on the inner carbon nanotube. The inner nanotube has a sudden change of its chirality (23) somewhere in the middle of it.

Figures 3 shows semi-conductor wafer. In figure 3, there are MWNT's (20.1 and 20.2) inserted in the semi-conductor wafer (14). The MWNT's are fixed in a semi-conducting wafer, preferably of silicon. The wafer is internally divided in a large number of isolatable electrical areas. Each tube is preferably set in a separate isolatable electrical area. Tri-state wiring (31.2) connects the isolatable electrical areas on the top of the wafer with the other electronic components. The bottom side contains the integrated tubes. It contains a variable number of at least 300, preferably more, tubes, all functioning as semiconductors, transmitters, and mechanical devices. The areas are, among other things, used for addressing the positions and for identification determination of the tubes.

Figure 4A to 4E shows the writing process. Figure 4A shows a MWNT that is attached to the wafer (14) and is consisting of an outer (21) and an inner tube (22), and the physical storage medium (12) that is consisting of the upper layer (41), the middle layer (42) and the lower layer (43). While the storage medium moves at a constant speed in X and Y directions, the MWNT is positioning above an empty position on the storage medium.

In figure 4E the indent is big enough to ensure proper reading of it when needed (45). Also the shape of the indent, caused by the direction of movement by the storage medium, the unique properties of the specific writing MWNT and the applied energy, leaves some information about this specific writing process.

Figure 5A to 5E shows the reading process. When a MWNT is at a proper position above the storage medium, reading will be done by bouncing at low energy of the MWNT on the storage medium, measuring the phase difference with the applied high frequency electromagnetic field at the moment of contact with the storage medium. Figure 5A shows that the inner tube (21) of the MWNT bouncing towards the storage medium. The storage medium has moved to the start position of the reading process. The MWNT is bouncing towards the storage medium. The high frequency electromagnetic field is coming across the MWNT.

Figure 5B shows the inner tube of the MWNT collides on the storage medium and the phase difference is measured with the applied high frequency electromagnetic field. Figure 5C shows that the inner tube of the MWNT bounces from the storage medium. Figure 5D shows that the inner tube of the MWNT collides another time with the storage medium, giving another phase difference. Figure 5E the moveable part of the tube of the MWNT collides with the edge of the indent, giving yet another phase difference. The sampled phase differences give enough information about the existence of the indent and some information about the shape of it.

Figures 6A to 6E shows the erasing process.

Figure 6A contains the storage medium/area (12), with a high deleted/valuable data ratio (61 an 62), containing valuable data (12) and deleted data (11), which area is due to be erased. In figure 6B the valuable data (62) of the area is copied to another area (63). In figure 6C, the original valuable data is logically deleted. Now that area only contains deleted data (61). Figure 6D shows the erasing by a laser diode. When the area only contains deleted data (61) and is ready to be erased, the storage medium (12) is going to be moved so that the area will exactly on top of the laser diode (15). The laser beam (66) will start and points at the area that is going to be erased (61). The temperature of the area with only the deleted data (61) is raised for a short period by the laser beam (66) of the laser diode (15). This will last long enough that the storage medium (12) in that place is stretched (64) and so the indents in the area will disappear. Figure 6E shows the storage medium (12) after the deleted area was erased. The storage medium (12) contains only an area with valuable data (62). The area where the deleted data used to be shows now an empty area without indents (67), that can be used for writing new data in it.

Figure 7A and 7B are showing the walking search process.
The storage medium (12) in figure 7A is deformed in 7B. The Smartey Tubes in wafer (14) will move above track 71.1 and 71.2 but will in case of figure 7B loose its path, which is detected on the reading tubes not seeing anymore information too early. There are two possibilities to solve this situation: a) a nearby Smartey Tube that happens to move also over the path track will be used, or b) if that isn't the case, reread, after repositioning the wafer, and reading in a somewhat changed direction.

Figure 8 shows a six-layered architectural system. Layer 6 (81) is the top layer, consisting of the General Unified Storage software structure. Layer 5 (82) shows the management layer. Layer 4 (83) consists of arbitrary interfacing software. Layer 3 (84) consists of only tables of the before mentioned layers. Layer 2 (85) consists of most electronics and mechanics, while layer 1 (86) consists of the actual storage device.

SUMMARY OF THE INVENTION

An object of the present invention is to create a viable solution for mass storage devices to achieve low-power consuming, low cost, ultra fast, high density, high capacity information storage apparatus.

A further object of the invention is to produce an information storage or non-volatile mass memory device that provides significantly increased (low/cost) storage density, fast access times and high transfer rates for electronic or electro-magnetic devices, such as computers, portables, communicators, audio, video and other devices, loose of preferred embodiments.

A further object of the present invention is to provide methods for storing information to generate ultra-fast transfer rates, as well as fast access times.

Another object is to provide viable solutions for storage capacity to achieve ultra-fast, high density and high capacity at small size, low cost and low power consumption, utilizing readily available, inexpensive methods.

Yet another objective is to enhance performance, functionality and reliability, better suited for emerging applications and new costumer requirements.

Other objects of the present invention are to provide a method for ultra high-density information storage in which:

- Reading and writing is performed at room temperature;
- Reading and writing of the information is accomplished by consuming less energy;
- Reading and writing of data is accomplished using conventional equipment;

- Reading and writing of data is accomplished by replacing as much hardware as possible by software (consuming less energy, benefiting small components and/or units, as well as adding flexibility and easy correctability to the storage apparatus);
- Reading and writing and erasing of information is accomplished;
- Reading, writing, deleting and erasing of information is accomplished;
- Reading of data is accomplished with low-power consummation and conventional, inexpensive equipment;
- Erasing of information is accomplished;
- Ultra fast, high volumetric, high-density writing of information is accomplished;
- Ultra fast, high volumetric, high-density reading of information is accomplished;
- Both ultra fast, high volumetric, high-density reading and writing of information is accomplished.

Yet other objects of the present invention are to provide a method for:

- Writing to a deformable medium with a deforming tool at least (more dense) than and faster than the current conventional methods;
- Reading of a deformable medium with a semiconductor tool at least faster than the current, conventional methods;
- Ultra fast, high volumetric, high-density information storage in which conventional equipment is being used;
- Ultra high-density information storage utilizing flexible and conventional equipment and replacing as much hardware as possible by software (firmware stored on internal memory);
- Achieving ultra high-density information storage with fast access and high data transfer rates;
- Ultra fast, high volumetric, high-density information storage in which the access to that information is controlled by management rules.

Accordingly, the following elements are disclosed:

A storage medium or restorable deformable phase-changing medium for storing information. Though the material of the physical storage medium can vary, the storage substrate is preferably a dense, conductive, moveable, strong, restorable deformable phase-change storage medium able to be restored to its original proportions (and position). As a best method, this invention makes use of a triple layer substrate, comprising top down: a dense, thin, conductive material, e.g. graphite, a substantively thicker interlayer, e.g. polymer foil, and a even more thicker than the middle layer an under layer, e.g. also polymer foil, on each other moulded together in a frame, moved in x and y directions by stepper motors.

- A deforming medium for storing information. A mechanical tool for writing is preferably a Multi Wall Carbon Nanotube (MWNT).
- A semiconductor medium for reading information. A semiconductor tool for reading/detecting/addressing/positioning is preferably a Multi Wall Carbon Nanotube, preferably with an inner wall longer than the outer wall.
- A semi-conducting medium for reading information. A semi-conducting tool for reading is preferably also a Multi Wall Carbon Nanotube (MWNT), preferably with an inner wall longer than the outer wall. The semiconductor for reading is preferably a Multi Wall Carbon Nanotube (MWNT), preferably with an inner wall longer than the outer one.
- Storage also to be utilized as memory: merging of non-volatile memory and information storage (and/or vice versa). A way to speed up the mechanical system of storage is to use smaller components. A tool for writing, reading and positioning as a semiconducting and mechanical tool within the same component, preferably a Multi Wall Carbon Nanotube can achieve ultra fast transfer rates, therefore acting as well as information storage as non-volatile memory.

According to the invention information is written by altering the physical properties of the surface of a storage medium in a semi-permanent way (i.e. so that the properties can be substantially restored to

their original values by an erasing action), by mechanical impact from a writing device. This facilitates very high-density writing at high speed. Preferably a multi-wall carbon nanotube attached to electrode is used as write element. In this case the surface of the medium is provided with a conductive layer. By applying a voltage between the device and the conductive layer the end of the nanotube is made to impact onto the surface, causing a semi-permanent local deformation, which is used to represent a unit of information such as a bit.

Preferably a conductive carbon layer (graphite) is used substantially as the outmost layer of the surface of the storage medium. Such a layer is very dense and ensures that the writing device will always hits something during writing. Preferably a layer of deformable material, such as a polymer layer, is provided underneath the graphite layer in the medium to provide the deformations. In this case the graphite layer is preferably sufficiently thin so that the deformation is substantially determined by the deformable layer and the graphite layer follows the deformation of the deformable layer.

Preferably, a heating element such as a laser diode is provided for locally heating the medium when information has to be erased by returning the properties of the surface to its pre-writing state. Preferably, the information is read with the same impart part, such as the nanotube, with which the information has been written. The deformation of the surface may be measured for example by measuring the duration of the time interval before a short circuit occurs between the nanotube and the conductive layer on the surface of the medium after the nanotube has been set in motion. As an alternative, the capacitance between the nanotube and the surface may be measured. In this way the expense of a separate read head is avoided.

In a further embodiment the effect of the unique peculiarities of the writing device are used to assist in positioning of the writing device during reading and/or writing. Due to variations in the writing device the changes in the physical properties of the surface will not be exactly the same everywhere. These variations must be eliminated as far as reading of the information is concerned, but the variations may be used to determine where the writing device is currently located relative to the medium. This can be used to position the writing device at an addressed location, initially when a new address has been supplied and/or for regulating a tracking during reading of successive information.

In a preferred embodiment the writing device contains an array of nanotubes which can be used in parallel to write information by means of impact on the surface. This increases writing speed. Due to imperfections, such as differences between the lengths of the nanotubes, or even the absence of nanotubes at certain locations in the array, differences will occur in the shape (e.g. width and depth) of the deformations of the surface of the storage medium. The effect of these differences is ignored when the information is decoded during reading. But during reading these differences can be sensed, preferably with the same array with which the information was written, and can be used to reposition the read head. To each pattern of sensed differences as a function of position (typically position in the array) one can assign a respective position of the read head relative to the position of the writing device during writing of the information. This position can be used to determine where the read head is located and to adjust the position of the read head at a desired address, or to assist in determining the addresses read by the read head. The assignment of a position of the read head to a sensed pattern may be performed for example by means of a look-up table, or an appropriately trained neural network, or a genetically trained function.

Other aspects of the present invention are methods for storing information by a mechanical, transmitting and semi-conducting tool deforming a restorable deformable state-changeable storage medium, causing bit-reading, bit-writing and positioning at selected locations.

Concerning the internal communications, another object of the present invention is to create a viable solution for mass storage devices to achieve low-power consuming, low cost, ultra fast, high density, high capacity information storage at high data rates.

Therefore, it is an object of the present invention to acknowledge and prove the existence of the so-called "Principle of Uncertainty", as its decelerating effects become noticeable after increasing beyond a certain quantity.

Another object of the present invention is to create a system that provides tools that can help to solve problems handling the uncertainty, (with awareness of the "Principle of Uncertainty"?) in high volume information storage.

Another object of the present invention is to provide methods to deal with the speed of the intern communication, the data access time, reliability and transfer times for high volume, high-density information storage.

Yet another object of the present invention is to provide a system according with awareness of the "Principle of Uncertainty" to provide an efficient way to deal with information storage and thus data structures, communication structures and thus memory structures and thus intelligence structures information storage in for high volume, high-density information storage.

Another object of the present invention is to provide methods, with awareness of the "Principle of Uncertainty", to deal with storage and thus communication and thus memory and thus intelligence structures for high volume, high-density ultra fast information storage

Yet another object of the present invention is to provide a system for high volume, high-density information storage in which data can be accessed as fast as possible.

Yet another object of the present invention is to provide a independent basic structure system Since individual developers should not and cannot set industrial standards as IEEE and ISO standards for information storage, interfacing and internal communications, the GUS structure system objective is to provide the necessary tools for information storage, maintaining the highest level of independence possible.

Yet another object of the present invention is to provide a system for information storage in which tools for unifying are provided.

Yet another object of the present invention is to provide concepts for industrial standardization for storage structures, thus communication and thus memory and thus intelligence structures for high volume, high-density ultra fast information storage.

Yet another object of the present invention is to provide a platform for methods for unification and industrial standardization to facilitate adjustment, correct ability, and flexible integration of existing and future technologies for electronic and electro-magnetic devices, that require information mass storage.

Yet another object of the present invention is to provide a method for integrating caching and memory into information storage.

Yet another object of the present invention is to provide a method for high volume, high-density, information and ultra fast information processing also to be able to function with conventional information recording devices, as well as RAID/Array's, SAN's and NAS' as well as with other existing and future technologies.

Yet another object of the present invention is to provide an architecture system to deal with existing and future capacity, transfer rates and costumer demands for intelligent computational devices.

Yet another object of the present invention is to provide a method for addressing information storage.

Yet another object of the present invention is to provide a method for caching in order to achieve fast data access and fast transfer rates of information storage.

Yet another object of the present invention is to provide a method for information storage in which writing and writing, deleting, erasing and storing of the data is accomplished by replacing as much hardware as possible by software, consuming less energy, benefiting small components and/or units, as well as adding flexibility and easy correct ability to the storage apparatus.

Yet another object of the present invention is to provide a method for information storage in which platform portability independence is accomplished.

Yet another object of the present invention is to provide a method for information storage in which required special interfacing can be achieved.

Yet another object of the present invention is to provide a method for volume information storage capacity in which reading, writing, deleting erasing and storing of information is accomplished.

Yet another object of the present invention is to provide a method for information storage capacity utilizing flexible and conventional equipment by replacing as much hardware as possible with software.

Yet still another object of the present invention is to provide a method for information storage capacity in which the information is controlled.

As far as the internal communications, in order for mass storage devices to achieve low-power consuming, low cost, ultra fast, high density, high capacity information storage at ultra-high data rates, the following objects are disclosed;

- The "Principle of Uncertainty" within information's storage
- The effects of the "Principle of Uncertainty" within information storage
- A solution to deal with the decelerating effects of the "Principle of Uncertainty" within information storage
- A best method to deal with the decelerating effects of the "Principle of Uncertainty" within information storage
- A method and apparatus that improves data rates to present information storage and memory technologies, which allows for fast access and transfer rates of stored information.
- A method and apparatus, which allows fast and reliable erasure of stored information.
- A method and apparatus which allows and addressing and positioning method for reading of written and/or stored information, which allows for fast access and transfer rates of stored information and which does not suffer from the drawbacks associated with present technologies for information storage and memory.
- A method and apparatus for storing information, and which does not suffer from density and erasing drawbacks associated with present probe scanning and memory technologies for information storage and memory.
- A method and apparatus to provide a an open, flexible architectural structure method to allow for fast data rates, reliable deleting and erasing, data storage security, platform portability, reliability, high capacity information storage management, addressing and positioning method for reading of written and/or stored information, and which does not suffer from the drawbacks associated with present technologies for information storage and memory.

Supplementary objects, features and advantages of the inventions will become apparent from the following specifications. Further advantageous arrangements of the invention are set forth in the claims, respectively sub claims. Hereafter, the term 'storage device' will refer to the combined description of high-density, high capacity information storage as well as to non-volatile mass memory.

DETAILED DESCRIPTION OF THE INVENTION

The storage device

When faced with the constraints of current magnetic storage disks and high density small scale processing storage devices, how to enhance storage densities, performance, functionality and reliability of fast, high capacity, high-density information storage, and how to create storage devices that are better suited to new emerging applications and new customer requirements, focus inclines to switch over to other promising technologies that can provide at least the same requirements without approaching essential and fundamental physical limits in the near future. One of these technologies looks into the possibilities of using carbon nanotubes as mechanical and semi conducting devices.

We have chosen to embark on storage capacity, creating and identifying state-changes in a storage medium, caused by carbon nanotubes because of the performance and density characteristics. Another advantage of using carbon nanotubes is that they consume very little power, solving also the problem of overheating that traditional transistors encounter at the nanoscale. In addition, carbon nanotubes are extremely durable, both mechanical and electrical. This invention will describe an apparatus and methods to create an information mass storage device, utilizing multi-wall carbon nanotubes for mechanical, semiconductor purposes, as well as a state-changing storage medium on which information can be stored.

The scope of using carbon nanotubes, in combination with a restorable deformable state–change storage medium, according to specific specification as further described in this patent, is to produce a small form factor information storage or mass memory device to provide significantly increased (low-cost) storage density and capacity, fast access times and high transfer rates for electronic or electro-magnetic devices, such as computers, portables, communicators, audio, video and other electronic or electro-magnetic devices with preferred embodiments and purposes, not herein limited.

In here, a storage device and methods are disclosed. The Carbon Nanotubes technology employs an array of several multiwall carbon nanotubes integrated in a silicon wafer. The inner walls of the nanotube that stick out towards the storage medium have tip of an average of about 10 nm. All tubes are individually connected by peripheral wiring on the wafer. In this concept, these nano-tips punch indentations into two thin polymer films, coated by a thin layer of graphite. The triple layer substrate is tightened within a frame of duralumium, which moves in x and y directions.

For writing purposes, the MWNT acts as a mechanical device. The process works by applying several times some electricity to selected parts of the wafer holding a MWNT. The write occurs by the inner wall sliding partly out the outer one, touching the storage medium. The indentation has a specific diameter, depth and shape, caused by mutual differences among the several MWNT's as a direct result of their chirality, length, diameter and angle of integration within the wafer. An electrical short cut of the charged tube by contacting the graphite film causes the inner tube to return to its original state. For reading purposes, the MWNT acts as a transistor. By adding somewhat lower energy this time to the tube, an indentation is detected. After repeating this process several times, while moving the storage medium in x and y directions, the indentation is scanned. The frequency signal received from the signature of the pit is used for addressing purposes. The tip of the MWNT can interpret patterns embedded in the film, without changing the pattern of the indentations. The indentations represent individual bits. To retrieve written data, unused locations and other information of the physical storage medium, there is a 2-way translation vehicle between logical data structures and the geographic area's on the physical storage medium. The feedback of the above-mentioned distinguished properties of the pits is used to correct and steer addressing interpretations.

The tips of the MWNT's give the ultimate density, whereas data rates are a combination of the bit-reading operation of the transistor function of individual MWNT's, combined with massive parallel operation of those tips. The more MWNT's, the higher the data rates. Recent experiments show that

individual tips of the tubes has a reading cycle of approximately 10 nanoseconds (ns), in which it will move during just about 3 ns, and remains inoperative for around 6 ns. The phase shift measurement has a resolution of a number of levels. During bit-reading, the tube scans the storage medium for a number of times. The stages of sensed depths are distinguished, so the tube detects the characteristics of the indentation it is dealing with. By measuring the phase shift in the applied frequency signal, it will take 190 Pico seconds to determine a characteristic of the indentation in each movement. The writing cycles of the tubes take somewhat more energy than the reading cycles. The down time on a bit-writing cycle to create an indentation is about 370 ps. After creating an dent, it takes about 3 ns to absorb the remaining energy, after which a tube applies a read cycle (3 ns) to control the result of this write. This means that the time between writing and reading takes about 6 ns. This will allow for extreme high data rates. Since the tips cause the ultimate density, an areal density of 2,7 Tb/cm^2, was establish, allowing even higher densities as the erasing process can be refined.

Erasing is achieved by thermal reflow of storage field as the medium is heated to about 180 degrees for a few seconds. The smoothness of the reflowed medium allows a storage field to be rewritten again repeatedly. Since this erasing process does not allow single-bit erasing, another system is developed to refine this method. A firmware system keeps track of the existence of unused places, not-deleted data and deleted data on the topographic of the physical storage medium and continuous arranges to sort it as geographically near as possible. Information blocks stored on the medium in the form of indentations are all linked to queued lists. The deleted information, selected to be physically erased, is placed for deletion into the delete lists. The valuable data is placed in the data lists. The system has also a list of physical geographical areas with information in it of links to valuable data that recites in the indentations in that geographical area. The system rearranges valuable data, reciting in an area with a high portion of deleted data to other areas with a lower portion by copying the data to it, and marking the original as deleted. When a specific geographical bounded area only contains deleted data, the links to them are removed and the area is erased by heating it for a short period by a laser beam, such that that area is stretched and the indentations in it are removed, where after the cooling down allows for the medium to pull tight to its original proportion. The area will be administrated as available for re-use.

At the Terabyte capacity, a new phenomenon arises creating decelerating internal communication effects. By applying a basic architecture structure system to the physical technology, the decelerating internal communication effects of the phenomena are addressed, creating additional communication quality-service towards the user/use.

Issues like low-power consumption, low-cost manufacturing, reading and writing reliability as a result of dependability on the strength of the carbon nanotubes, reliable erasing and addressing techniques are taken of. For now, this storing system and techniques could easily customized to replace the perpendicular longitude magnetic recording hard disk drives. Other future perspectives like increasing data rates and density are promising.

Figure 1A shows a side view of a "General Unified Storage" (or "GUS") storage device in accordance with the present invention.

Above the top of the storage medium (12) resides the wafer (14) in which the MWNT's are attached. The storage medium is attached on a frame (13). This frame is connected via cogwheels (16.1 and 16.2) driven by motors (11.1 and 11.2) that move it in X direction. Other motors move it in the Y direction. All motors are positioned underneath the storage medium. The laser diode (15), used for erasing process, is mounted underneath the medium.

The invention consists of small form factor information storage and/or memory device that can be used with a computational system as a type of 'Carbon Nanotube-based', information storage and/or memory device. The dimensions and housing of the memory and/or storage device may vary broadly. Therefore, the storage device can easily be adjusted for use of data and/or information mass storage in PC's, supercomputers, servers, minicomputers, (video) camera's, communicators, mobile and cellular

phones, notebooks, PDA's, wrist devices, audio and video equipment, as well as any other technology, requiring digital electronic or electro-magnetic information storage or mass memory. Hereafter, the meaning of the word 'information storage' within this patent, should also be red as including 'mass memory'.

Carbon nanotubes: the Smartey Tubes

Carbon nanotubes show a crystalline form, with a cylindrical structure, of carbon. They consist of a graphitic plane rolled into a tube and have a nanometric diameter of tens of atoms (10E-9 meter = 1 nanometer). Being a member of the fullerene family, carbon nanotubes have the capacity to conduct electricity as well as copper. However, carbon nanotubes are stronger than steel and as hard as diamond.

The electrical behaviour is one of the remarkable properties of carbon nanotubes. The carbon nanotubes can be anywhere from metallic to insulating, including semi conducting, depending on the exact arrangement of the atoms in the tube. A way to characterize the arrangement of the atoms in the tube is known as "chirality", which reflects the property of the tube. The three basic forms of chirality are: armchair, zigzag and chiral. There is a direct correlation between chirality and the electrical conductivity.

Carbon nanotubes can be divided in two groups: single wall carbon nanotubes (SWNT) and multi-wall carbon nanotubes (MWNT). For the invention we use multi-wall carbon nanotubes. Multi-wall carbon nanotubes have the following properties:
MWNT are ballistic conductors, despite the interactions expected between the different layers. A way to measure the electrical conductance of MWNT was invented in 1998 by Walt de Heer and colleagues at the Georgia Institute of Technology in the US. They found that all MWNT's have practically the same conductance ($G_0 = 2e^2/h$) and that their dependence of the resistance on length is very weak.

Furthermore, they found that the electrical current that can be passed through a MWNT corresponds to a current density in excess of 10^7 amps per square centimetre. In comparison: a classical resistance would vaporize as a consequence of the fact that the power dissipated by such a current would heat the resistance. Since the nanotubes are not vaporizing, it is very likely to assume the electrons in nanotubes are strongly decoupled from the lattice. MWNT consist of several concentrically arranged SWNT, therefore, one would not expect them to work as one-dimensional conductors. Electrons would not be restricted to one layer, in case bordering carbon layers interact as in graphite. Peeling of a carbon layer from a carbon nanotube is quite complicated. Each carbon atom is powerfully fixed to three other atoms in a sheet of graphite. This makes carbon nanotubes very durable.

In view of the fact that the MWNT's need to be fixed to wiring to be able to conduct certain purposes, several MWNT's are integrated within a wafer, each one into one isolatable electrical area of a Silicon wafer. For reasons of structures and properties of both crystals, the outer wall of each MWNT becomes tightly fixed in a separate isolatable electrical area of the silicon wafer. This leaves the inner wall 'free' to carry out several functions within the rigid outer wall to the opposite end of the fixed end. This can also be done the other way around; the inner wall fixed and the outer wall movable around the inner wall, depending on what is convenient for fixing purposes.

The unique mechanical and semi conducting properties of these MWNT's demonstrate to be a rich source to lead to information storage applications in materials and devices. Hereafter these described MWNT's will be called 'Smartey Tubes' to distinguish them from other sorts of carbon nanotubes.

The mass storage device uses MWNT's according to the hereafter-mentioned qualifications: an open, fixed nanotube and a moving tube, where the moving tube is preferably somewhat longer than the fixed one and where the moving tube is either left or right chiral and twisted.

Figure 2A to 2B shows an example of how a Smartey Tube, as described above, can look like. In this figure, a MWNT (20) consist of (at least one) outer nanotube (22) with some chirality and length and (at least one) inner carbon nanotube (21). In figure 2B the outer nanotube has been opened to give a better view on the inner carbon nanotube. The inner nanotube has a sudden change of its chirality (23) somewhere in the middle of it.

Utilization advantages of these Smartey Tubes as semiconductors are that they are ideal transistors, very small compared to the nowadays-used silicon transistors, consuming very little power. The last mentioned feature benefits low cost and is responsible for minimal temperature raise. Also, the Smartey Tubes feature both transducer and mechanical properties, making them usable for very high transfer rates, when used in the right manner. Furthermore, differences on diameter, length, conductivity, and chirality or twist between the Smartey Tubes allows for distinguished signatures, to be utilized for positioning and addressing purposes.

The semiconductor wafer

The Smartey Tubes are fixed in a semi-conducting wafer, preferably of silicon. Tri-state wiring connects the isolatable electrical areas on the top of the wafer with the other electronic components. The bottom side contains the integrated Smartey Tubes, each one preferably set in a separate isolatable electrical area. The wafer is internally divided in a large number of isolatable electrical areas and contains a variable number of at least 300, preferably more, Smartey Tubes, all functioning as semiconductors, transmitters, and mechanical devices. The areas are, among other things, used for addressing the positions and for identification determination of the Smartey Tubes.

Figures 3 shows semi-conductor wafer. In figure 3, there are MWNT's (20.1 and 20.2) inserted in the semi-conductor wafer (14). The MWNT's are fixed in a semi-conducting wafer, preferably of silicon. The wafer is internally divided in a large number of isolatable electrical areas. Each tube is preferably set in a separate isolatable electrical area. Tri-state wiring (31.2) connects the isolatable electrical areas on the top of the wafer with the other electronic components. The bottom side contains the integrated tubes. It contains a variable number of at least 300, preferably more, tubes, all functioning as semiconductors, transmitters, and mechanical devices. The areas are, among other things, used for addressing the positions and for identification determination of the tubes.

For positioning, several characteristics of the tubes are important for identification determination:
Location of the individual tubes;
The variable depths, shape, and dimensions of the indents, caused by the tube hitting the physical storage medium, are dependent of the vertical position of the inner tube in relation of the outer tube and the applied force at the time of writing;
Bottom depths of the indents in the physical storage substrate, caused by the tubes.

The physical storage medium.

Akita et all of the Osaka Prefecture University (Appl. Physics 33) showed in a conference proceedings article of July 11, 2000, called "Nanoindentation of polycarbonate using carbon nanotube tip" that it is feasible to make nanoindents by a nanotube in a polycarbonate surface.

The physical storage substrate is a dense, conductive, moveable, strong, restorable deformable (state-change) storage medium able to be restored to its original proportions and position. The physical storage substrate preferably comprises a triple layered substrate, encompassing a dense, thin, conductive material, e.g. graphite to prevent to prevent buckling of the nanotubes and to support the electrical conduction of the medium, damped on a substantively thicker interlayer, e.g. polymer foil, and an even more thicker than the middle layer a lower layer, of also polymer foil. The complete substrate is subsequently spherically tightened and stretched on a stiff frame, preferably made of

duralunium. The frame with the storage substrate is moved in x and y directions, e.g. driven by stepper motors.

To prevent a tip of a Smartey Tube from pinning through the polymer, a strong and dense carbon layer is damped upon the surface of the middle layer. The upper layer of the physical storage medium needs to be conductive to cause the moving tubes to redraw to the original position by a momentarily electrical short-circuit at hitting the upper conductive layer. The coating is preferably subject to restorable deformations (phase changing), provided that it should be able to restore to its original state. Considering the above-mentioned advantages, graphite is a preferred material. In addition, graphite can easily be damped on several substrates. These special properties of graphite make the material supreme to serve as an upper layer substrate of the deformable physical storage medium.

By increasing the energy to an isolatable electrical area in the semi-conducting wafer in which a Smartey Tube is integrated, the moving tube will move, hitting the storage medium substrate.

An alteration on nanoscale is an alteration of the surface of said medium, which alteration has width between 10 and 50 nanometer. A Smartey Tube hitting, with enough energy, on to the upper layer, will create a deformation on nano scale. This deformation will pass on to the middle and underlying layer so a Smartey Tube is suitable to create indentations on both the upper, as well as the underlying layer. A Smartey Tube will create a restorable deformation state-change by hitting the upper layer and subsequently the layer underneath in the form of an indent. To cause erasing, a laser diode is situated underneath the storage medium substrate. The somewhat thicker polymer layer at the foundation will partly absorb the heat of the laser diode in case of erasing. By warming up the middle layer, both polymer layers will pull tight again, in turn pushing the indentation in the upper graphite layer back.

The main advantage of the polymer foil layers is that the structure is extremely dense and durable, as well as being mechanical to induce short-circuits when in touch with frequency fields, created by adding kinetic energy to the wafer and the integrated Smartey Tubes. Additionally, both graphite and polymer are largely available, relatively inexpensive and can be easily processed into a very smooth and ultra-thin film. Besides, any material having the advantages of the mentioned characteristics of the graphite could be used as a deformable medium, the same goes for the polymer.

Movements of the storage medium

While in writing and/or reading operation, the physical storage medium moves very fast in x and y directions. The storage medium is continuously moving in x and y directions, preferably driven by motors in a frame, using software corrections for movement anomalies. By adding energy to the wafer and the tubes, the firmware causes the tubes to hit or touch the storage medium on numerous places. During these operations, the Smartey Tubes execute their essential functions, causing addressing, positioning, bit writing and bit reading.

An option can be to use stepper motors to accomplish the positioning of the device. For each direction (x and y) three motors can be used, another two for driving with different step angle and one smaller correction motor, also with another different step angle. The six motors are all individually driven by the firmware. For sake of fine position and correction there is a continuous update and backwards coupling of the measured reached position of the storage medium toward the smartey tubes. This measured information is transformed and applied as modifications and small corrections to the movement table and functions in the devices internal memory. The information transfers by the tubes to or from the storage medium are only done when the storage medium is at speed.

Addressing.

Addressing is needed to retrieve already stored information and for storing new information on the medium. Therefore you need a two-way route for the addressing, one from the physical medium towards the information and one from the logical data structure toward the physical medium. There are

2 addressing automata, one for the road towards the medium and one for the route back. The automaton towards the medium is tuned to try to store as much corresponding data on near physical places on the medium.

Information on which tube has written a specific bit part of the information can, with a reasonable probability, be detected on reading process of the information. This helps the automaton in a walking search method to find track to stored information in case the exact physical location of the data on the medium is misread.

Figure 7A and 7B are showing the walking search process.
The storage medium (12) in figure 7A is deformed in 7B. The Smartey Tubes in wafer (14) will move above track 71.1 and 71.2 but will in case of figure 7B loose its path, which is detected on the reading tubes not seeing anymore information too early. There are two possibilities to solve this situation: a) a nearby Smartey Tube that happens to move also over the path track will be used, or b) if that isn't the case, reread, after repositioning the wafer, and reading in a somewhat changed direction.

The isolatable electrical areas within the wafer are used to move the inner tube of an individual Smartey Tube to an electrically conductive state-changeable surface by adding energy to an individual isolatable electrical area that contains only one Smartey Tube.

Electrical areas that contain none or more than one Smartey Tubes will be detected and excluded the first time the General Unified Storage is started. The semiconductor tool for detecting (scanning), and positioning and addressing and reading is preferably a Multi Wall Carbon Nanotube, preferably with an inner wall longer than the outer wall. While the outer wall remains integrated within the wafer crystal, the inner wall, powered through the wafer, will scan for an indentation in the storage medium. If the semiconductor medium detects an indentation, it will remember the physical position by combining it with the current state of the stepper motors and the positioning of the detecting MWNT in the wafer. Then, the inner tube of said MWNT will measure shape properties of said indentation by scanning the shape properties of said indentation. Together, this information will be used for addressing. The combination of detecting, positioning and addressing will result in a read. Both the semi-conducting as the physical differences between the MWNT's will be utilized for identifications purposes. These structures for positioning and addressing will be used during the rest of the life of the storage unit.

To retrieve written data, unused locations and other information of the physical storage medium, there is a 2-way translation vehicle between logical data structures and the geographic area's on the physical storage medium. The feedback of the above mentioned shape properties is used to correct and steer addressing interpretations:

- To verify the correct interpretation of addressing of read information
- To detect that the interpretation of the addressing of the read information is not in correspondence with the expected address
- To form a vehicle to reposition to a proper known address

As a result of the continuously moving the storage medium is in x and y directions, and some stretch in the storage medium, part of the addressing method is to reposition on the hand of the indents and the carbon nanotubes. The variety of the amount of tubes hands a recognition and thus detection of a positioning of a bit-writing. As a consequence, this information can be used as a method to find back a point when a sequence is lost.

Because different physical media may need quite different addressing algorithms, there are a number of addressing classes possible. The upper layers of the "General Unified Storage" ("GUS") system's are indispensable for high speed transfer times and data access rates within a high capacity storage device, containing, among other things, addressing algorithms, to address these certain classes of addressing.

Writing of the deforming medium on the deformable medium.

Writing is performed as follows. By increasing the energy to the isolatable electrical areas within the wafer, in which one Smartey Tube is located, the tip of the inner tube is directed towards the storage medium, deforming the storage medium by creating a state-change in the form of an indentation. The outer wall remains integrated within the Silicon wafer. After hitting the storage medium the inner tube, as a result of short-circuit, will redraw to the originally desired position within the outer tube. This process will be repeated a number of times to complete the indentation. After this process, the write is completed.

Now, the indentation itself will show a variable depth and shape, depending on the length, angle and chirality of the Smartey Tube. This is distinguished as a unique signature. The write in turn will be typically registered by the proper place on the storage medium, using software corrections for movement aberrations and elasticity of the storage medium.

Figure 4A to 4E shows the writing process. Figure 4A shows a MWNT that is attached to the wafer (14) and is consisting of an outer (21) and an inner tube (22), and the physical storage medium (12) that is consisting of the upper layer (41), the middle layer (42) and the lower layer (43). While the storage medium moves at a constant speed in X and Y directions, the MWNT is positioning above an empty position on the storage medium.

Writing is established by bouncing the inner tube of the MWNT at high energy towards the storage medium so an indent will be made. In figure 4B the inner tube (21) of the MWNT moves at high energy towards the storage medium, leaving an indent in it. After the indent was made, the inner tube bounces back to its original state as shown in figure 4C. The storage medium is still moving into X and Y directions. The MWNT bounces a number of times towards the storage medium and back, each time enlarging the indent as shown in figure 4D. The dimensions, shape and depths of the indentations will depend on the angle, length, chirality and diameter of the particular tubes.

In figure 4E the indent is big enough to ensure proper reading of it when needed (45). Also the shape of the indent, caused by the direction of movement by the storage medium, the unique properties of the specific writing MWNT and the applied energy, leaves some information about this specific writing process.

Reading of the deforming medium on the deformable medium.

The method of the semiconductor use of a Smartey Tube is that for bit reading the moveable part of the tube will pull out again by adding energy with lower energy than the write cycle. The moveable part of the tube detects the variable depths and/or shapes, causing positioning and identification of the occurred imprint (state-change) on the physical storage medium to obtain addressing information for reading by measuring the phase shift of the applied frequency signal and transmits this to inside the isolatable electrical areas within the wafer. After sensing these imprints (state-changes), further processing of the reading is performed by the "General Unified Storage" system, using the signature of the indents and the, corrected, determined place of the imprint on the medium.

Figure 5A to 5E shows the reading process. When a MWNT is at a proper position above the storage medium, reading will be done by bouncing at low energy of the MWNT on the storage medium, measuring the phase difference with the applied high frequency electromagnetic field at the moment of contact with the storage medium. Figure 5A shows that the inner tube (21) of the MWNT bouncing towards the storage medium. The storage medium has moved to the start position of the reading process. The MWNT is bouncing towards the storage medium. The high frequency electromagnetic field is coming across the MWNT.

Figure 5B shows the inner tube of the MWNT collides on the storage medium and the phase difference is measured with the applied high frequency electromagnetic field. Figure 5C shows that the

inner tube of the MWNT bounces from the storage medium. Figure 5D shows that the inner tube of the MWNT collides another time with the storage medium, giving another phase difference. Figure 5E the moveable part of the tube of the MWNT collides with the edge of the indent, giving yet another phase difference. The sampled phase differences give enough information about the existence of the indent and some information about the shape of it.

The deleting and erasing process.

Erasing is the actual destroying of deleted info on the medium to make room for new data. The "GUS" software system keeps track of the existence of unused places, not-deleted data and deleted data on the topographic of the physical storage medium and continuous arranges to sort it as geographically near as possible.

Information blocks stored on the medium in the form of indentations are all linked to queued lists. The deleted information selected to be physically erased is placed on deletion into the delete lists. The valuable data is placed in the data lists. The system has also a list of physical geographical with information in it of links to valuable data that recites in the indentations in that geographical area. The system rearranges valuable data, reciting in an area with a high portion of deleted data to other areas with the lower portion by copying the data to it, and marking its original as deleted. When a specific geographical area only contains deleted data, the links to them are removed and the area is erased by heating it for a short period by a laser beam, such that that area is stretched and the indentations in it are removed.

The list heads of the lists are kept in a number of fixed specifically reserved for the storage system administration, geographical areas so that, on power loss, or system rearranging, those lists can be recovered. The deleting process is established by logically moving the information within the software of the "General Unified Storage" system to the deleted data queue by the "GUS" software. The information, not to be erased, will be copied to geographically logical areas. This selective copying allows for selecting information to be erased from the information not to be erased.

For erasing purposes, a laser diode can be sited underneath the physical storage medium. The laser diode, located underneath the triple polymer substrate, should be able to point a fine beam towards the substrate. The erasing process is done by temporarily increasing local temperature of approximate 180 °C by laser diodes to the underside of the storage medium on big enough local areas that contain only deleted data. By heating this part of the storage medium for a short time it pulls tight to its original proportion. The area will be administrated as available for re-use.

Figures 6A to 6E shows the erasing process.
Figure 6A contains the storage medium/area (12), with a high deleted/valuable data ratio (61 an 62), containing valuable data (12) and deleted data (11), which area is due to be erased. In figure 6B the valuable data (62) of the area is copied to another area (63). In figure 6C, the original valuable data is logically deleted. Now that area only contains deleted data (61). Figure 6D shows the erasing by a laser diode. When the area only contains deleted data (61) and is ready to be erased, the storage medium (12) is going to be moved so that the area will exactly on top of the laser diode (15). The laser beam (66) will start and points at the area that is going to be erased (61). The temperature of the area with only the deleted data (61) is raised for a short period by the laser beam (66) of the laser diode (15). This will last long enough that the storage medium (12) in that place is stretched (64) and so the indents in the area will disappear. Figure 6E shows the storage medium (12) after the deleted area was erased. The storage medium (12) contains only an area with valuable data (62). The area where the deleted data used to be shows now an empty area without indents (67), that can be used for writing new data in it.

Internal communications, data rates and the "Principle of Uncertainty"

Storing of the information of ultra-high information storage capacity is preferably established and managed by software, such of the software of the "General Unified Storage" system. A problem with high-density information storage and large storage capacity are the data rates. Data rates are related to the mode of recovery of information and/or data stored. The "Principle of Uncertainty" is a phenomenon that affects data rates. The effects of this phenomenon become readily noticeable in decelerating transfer rates and access times when the information storage capacity exceeds about several tens of Terabytes.

The "Principle of Uncertainty" becomes evident in the ultra-high capacity information storage device incorporated in this patent. Based on his theory on predictability at a growth of information storage and/or memory, dr. W.H.M. Versteegen, developed in the early nineties a hypothesis of diminishing predictability as capacity of information storage increases. In assignment of W.H.M. Versteegen of the University of Leiden, A. Simonič of Dalhousie University of Halifax, Nova Scotia, Canada, has worked out an extension of Lomonosov's techniques in an article called "An extension of Lomonosov's techniques to non-compact operators" on July 6, 1995, proving the effect of the "Principle of Uncertainty" for information storage.

Since the object is to create an ultra-high capacity, ultra-high density, high data rate information storage device and methods, including the aforementioned amenities, the effects of uncertainty need to be directed. Since the effects of uncertainty become readily noticeable above the Multi-Terabyte information storage capacity, and exerts its decelerating influence on anything, especially in data rates, the "Principle of Uncertainty" will be explained and described hereafter. A method to deal with these effects will be disclosed and incorporated herein.

The cause of this phenomenon is actually easy to explain, or rather even an open door. When information storage capacity increases, a choice has to be made to approach a certain part of the total amount of the existing storage. The bigger the amount of total storage, and, as a consequence, the smaller the part of the desired information (part), the more has to be done to retrieve/recover the desired information. A simple illustration to clarify this: A needle in a sewing-kit is easier to be found, than a needle in a haystack. If one wants to find the needle in a haystack, the fastest way to find the needle is to divide the stack in parts and systematically and methodically search parts of the haystack.

So, as a direct result of increasing storage capacity, the result of this effect is the decelerating speed on transfer times and access rates. This so far unidentified effect manifests itself when information storage becomes exceeding the Multi-Terabyte capacity. This phenomenon, inhere called the "Principle of Uncertainty", shows a non-linear expansion of uncertainty as capacity of information storage increases. The amount of uncertainty will have a coupling, decelerating reflection on the speed of the internal communications (such as addressing, erasing, data-management etc), and also a coupling reducing effect on access time of the information, and a coupling slow up reflection on transfer times.

Since the object is to create an ultra-high capacity, high density, high data rate information storage device and methods, including the aforementioned amenities, the effects of uncertainty need to be directed. Since the effects of uncertainty become readily noticeable above the Multi-Terabyte information storage capacity, and exerts its decelerating influence on anything, especially in data rates, a methodical, thorough solution to the effect of the "Principle of Uncertainty" was needed to be created.

As a result of the effects of the principle, the internal communications show an expansion of uncertainty as the amount of information storage increases beyond a certain stage. While increasing storage capacity, internal communications, such as writing, reading, erasing, data-management etc, within the information storage will slow down. As a consequence of decelerated internal communications, the slower the transfer times and access data rates. The lower the transfer times and access rates, the more time it takes to recover, retrieve and access the information. With other words: the amount of 'uncertainty' increases non-linear with the increase of information storage capacity,

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